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ORIGINAL ARTICLE

Computer-navigated minimally invasive total knee arthroplasty for patients with retained implants in the femur

Sung-Yen Lin [a,b], Chung-Hwan Chen [b,c], Peng-Ju Huang [b,c], Yin-Chih Fu [b,d], Hsuan-Ti Huang [a,b,*]

[a] *Department of Orthopedics, Kaohsiung Municipal Ta-Tung Hospital, Kaohsiung Medical University, Kaohsiung, Taiwan*
[b] *Department of Orthopedics, School of Medicine, College of Medicine, Kaohsiung Medical University, Kaohsiung, Taiwan*
[c] *Division of Orthopedics, Department of Adult Reconstructive Surgery, Kaohsiung Medical University Hospital, Kaohsiung, Taiwan*
[d] *Department of Orthopedics, Kaohsiung Municipal Hsiao-Kang Hospital, Kaohsiung Medical University, Kaohsiung, Taiwan*

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Abstract Total knee arthroplasty (TKA) in patients with knee arthritis and retained implants in the ipsilateral femur is a challenge for knee surgeons. Use of a conventional intramedullary femoral cutting guide is not practical because of the obstruction of the medullary canal by implants. Previous studies have shown that computer-assisted surgery (CAS) can help restore alignment in conventional TKA for patients with knee arthritis with retained femoral implants or extra-articular deformity, without the need for implant removal or osteotomy. However, little has been published regarding outcomes with the use of navigation in minimally invasive surgery (MIS)-TKA for patients with this complex knee arthritis. MIS has been proven to provide less postoperative pain and faster recovery than conventional TKA, but MIS-TKA in patients with retained femoral implants poses a greater risk in limb malalignment. The purpose of this study is to report the outcome of CAS-MIS-TKA in patients with knee arthritis and retained femoral implants. Between April 2006 and March 2008, eight patients with knee arthritis and retained femoral implants who underwent the CAS-MIS-TKA were retrospectively reviewed. Three of the eight patients had extra-articular deformity, including two femur bones and one tibia bone, in the preoperative examination. The anteroposterior, lateral, and long-leg weight-bearing radiographs carried out at 3-month follow-up was used to determine the mechanical axis of lower limb and the position of components. The mean preoperative femorotibial angle in patients without

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* Department of Orthopedics, Kaohsiung Municipal Ta-Tung Hospital, Kaohsiung Medical University, Number 68, ZhongHua 3rd road, Cianjin district, Kaohsiung, Taiwan.
E-mail address: hthuang@kmu.edu.tw (H.-T. Huang).

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extra-articular deformity was 3.8° of varus and was corrected to 4.6° of valgus. With the use of navigation in MIS-TKA, the two patients in this study with extra-articular femoral deformity also obtained an ideal postoperative mechanical axis within 2° of normal alignment. Overall, there was a good restoration of postoperative mechanical alignment in all cases, with a mean angle of 0.4° of varus. No limb malalignment or component malposition was found. In clinical assessments, there were also significant improvements in knee specific scores, functional scores, and motion arc. The results of this study suggest that navigation can help achieve accurate alignment and proper prosthesis positioning in MIS-TKA for patients with retained femoral implants and for whom intramedullary rod guidance is impractical.

Introduction

It is not uncommon for orthopedic surgeons to encounter patients with prior femoral fractures who have developed end-stage arthritis requiring total knee arthroplasty (TKA), although the incidence of arthritis is considerably lower than that after tibial plateau fractures [1]. However, TKA is difficult to perform in patients with knee arthritis and retained implants in the ipsilateral femur because the medullary canal obstruction by implants precludes the use of conventional intramedullary (IM) instrumentation [2,3]. Implant removal is usually suggested prior to TKA, but this may increase the risk of intraoperative fracture and result in an inferior outcome [4,5]. The use of an extramedullary (EM) guide and free-hand cutting are common options in these situations, but both options are less accurate than a conventional IM guide and mostly rely on the experience of the surgeons [6,7]. Therefore, there is a need to improve and optimize the outcomes of these patients.

Computer-assisted surgery (CAS) has been used in joint replacement surgery for years and has improved radiographic accuracy in both TKA [8,9] and minimally invasive surgery TKA (MIS-TKA) [10,11]. Moreover, obviating the need for IM guiding rod, navigation (NA) system has been reported to be suitable for application in some complex arthritic knee disorders. Previous studies have shown that NA can help restore alignment in TKA for patients with knee arthritis with retained femoral implants [2,3] or extra-articular (EA) deformity [12–16], without the need for implant removal or osteotomy, but most previous studies have reported on conventional TKA. By comparison, MIS-TKA has caused less soft tissue damage, with the advantages of less postoperative pain and rapid functional recovery [17,18]. However, little has been published regarding outcomes with the use of CAS in MIS-TKA for patients with retained implants or EA deformity. Therefore, in this study, we reported the results of CAS-MIS-TKA in patients with knee arthritis and retained implants in the ipsilateral femur.

Methods

Between April 2006 and March 2008, we performed MIS-TKA in eight patients with knee arthritis and implants in the ipsilateral femur. All surgeries were performed by the senior author in this study. Because the retained implants obstructed the medullary canal and precluded the use of a conventional IM femoral cutting jig, all the knees were operated on using the minimedial parapatellar approach with the assistance of a computed tomography-free Vector Vision knee NA system (BrainLAB, Munich, Germany). Posterior stabilized prostheses (NexGen, Legacy Knee LPS-Flex, Zimmer, Warsaw, IN, USA), were used in all of the patients and all components were fixed with bone cement.

The surgical procedure was started with a 12-cm medially curved skin incision extending from the superior pole of the patella to the top of the tibial tubercle. The joint was entered through the minimedial parapatellar arthrotomy from 1 inch above the superior pole of the patella to the tibial tubercle. The patella was then displaced laterally, but not everted. We used an image-free NA system with an optical tracking unit that detected reflecting marker spheres using an infrared camera. After arthrotomy, two reference arrays with passive marker spheres were fixed to the distal femur and proximal tibia. To avoid collision of femoral implants, a smaller guide pin (2-mm Kirschner wire) was used first. The guide pin was inserted into the anterior lateral cortex of the distal femur 10 cm proximal to the tibiofemoral joint line and plunged through the posterior cortex. After confirming that the pin did not violate the implants, we changed the pin to a 4-mm bicortical anchoring screw. Another 4-mm bicortical anchoring screw was placed into the tibia 10 cm distal to the tibial plateau for mounting the referencing trackers. The rotation center of the hip joint was first determined using a pivoting procedure. Then, the registration process was started and the special bony landmarks (the most prominent points of the medial and lateral epicondyles and the anterior sulcus) and the articular surface of the femoral condylar and tibial plateau were digitized using a NA pointer. After registration was completed, the system created an adapted bone model of the specific patient's anatomy based on these data, and offered a planning proposal for component orientation. MIS Multi-Reference 4-in-1 instrumentation (Zimmer) was used for bone cutting and the femur and tibia resections were then performed in sequence with the NA cutting guides. The ligamentous balance was checked using both the manual method and NA after the trail components were inserted, and final adjustments were made to ensure soft-tissue balance. Then, the patella was resurfaced to match the thickness of the patellar components. Finally, all components of the prosthesis were cemented into place.

Postoperative care and physical therapy were the same as that of regular TKA in our hospital.

After each patient was discharged from the hospital, postoperative follow-up was done at 2 weeks, 6 weeks, 3 months, 1 year, and every year thereafter on a routine basis. Preoperative and postoperative clinical and radiographic records were reviewed retrospectively for this study. All patients consented to study participation, and all aspects of the study were approved by the institutional review board at Kaohsiung Medical University Hospital (No. KMUH-IRB-20110230). Clinical assessments, including the Knee Society clinical rating scales (KSS), comprising both knee and functional subscores, and range of motion (ROM) were recorded preoperatively and at each follow-up. The full-length standing radiograph as well as the standard anteroposterior and lateral radiographs of the operated knee carried out 3 months after the operation was used to determine the mechanical axis (MA) and the position of components. The MA was defined as the angle between a line from the center of the hip to the center of the tibial tray, and a line from the center of the tibial tray to the center of the ankle joint. The desired MA after reconstruction was 0°. In assessing the position of the components, the lateral distal femur angle (LDFA) and medial proximal tibial angle (MPTA) were measured (Fig. 1A). The LDFA was defined as the lateral angle between a line from the center of the femoral head to the center of the knee and a line parallel to the distal surface of the femoral component [19]. The MPTA was defined as the medial angle between a line from the center of the ankle to the center of the knee and a line parallel to the surface of the tibial component [19]. The desired component alignments were 90° in the LDFA and 90° in the MPTA. The sagittal alignments of component position, including femoral flexion and tibial slope, were evaluated according to the Knee Society TKA roentgenographic evaluation form (Fig. 1B) [20].

We used JMP software (SAS, Cary, NC, USA) to analyze the data. The Wilcoxon signed rank test was used to compare the values of the KSS and ROM prior to surgery and at the 2-year follow-up. A p value < 0.05 was considered significant.

Results

Eight patients (4 women and 4 men) with an average age of 65.8 years (ranging from 63 years to 66 years) were enrolled in this study. No patient had rheumatoid arthritis or severe osteoporosis. All patients had suffered from EA femoral fractures and underwent reduction and internal fixation after injury. The implants were not removed after bone union and left *in situ* for more than 10 years. Three patients had residual nails and five had residual plates in the femur. The average distance from the distal side of the implant to the intercondylar notch was 5.86 cm. Clinically, a statistically significant increase of knee motion arc was noted. The KSS, including the knee specific score and function score, also significantly improved after surgery (Table 1). Postoperative

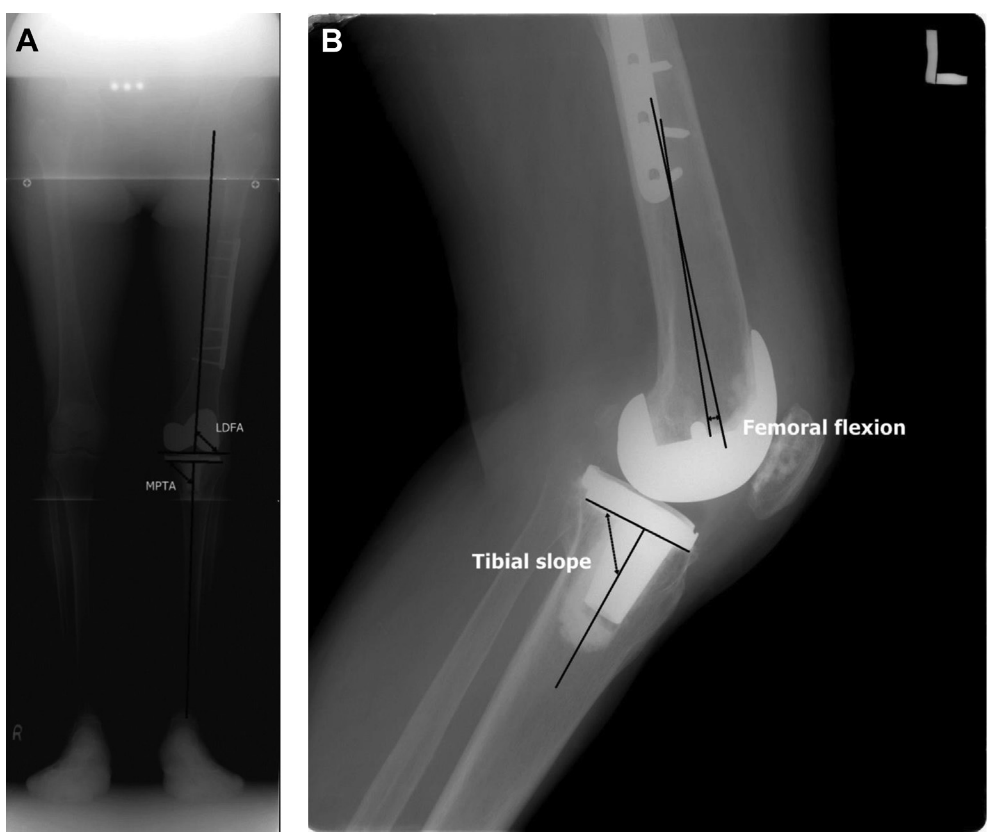

Figure 1. Postoperative radiographs of a 62-year-old woman with retained femoral implants (Patient 7 in Table 1). (A) Full-length standing radiograph demonstrating the lateral distal femur angle (LDFA) and medial proximal tibial angle (MPTA). (B) Standard lateral radiograph demonstrating the femoral flexion and the tibial slope.

Table 1 Results of range of motion, knee scores, and functional scores.

Patient no.	ROM / motion arc (°)				Knee scores		Functional scores	
	Preop		Postop		Preop	Postop	Preop	Postop
1	5–110	105	0–120	120	45	91	45	95
2	5–110	105	0–120	120	49	94	45	85
3	5–95	90	0–110	110	39	87	30	90
4	10–100	90	0–110	110	45	86	40	90
5	0–95	95	0–120	120	51	91	40	85
6	5–110	105	0–115	115	54	90	45	90
7	5–90	85	0–110	110	41	92	45	85
8	0–100	100	0–120	120	49	90	40	90
Mean		96.8		115.6[a]	40.5	90.1[a]	41.3	88.8[a]

Postop = postoperative; Preop = preoperative; ROM = range of motion.
[a] $p < 0.05$.

recovery of the patients was uneventful, and neither deep infections nor major complications occurred after surgery. The pre- and postoperative radiographs were used for comparison; the results are shown in Table 2. Three patients had EA deformity, including two femur bones (25° and 5.6° of varus) and one tibia bone (9° of varus), in the preoperative examination. An outlier was defined as >3° of deviation from the ideal axis, and there was no outlier in the aspect of the postoperative MA or the position of the component. The mean preoperative femorotibial angle in patients without EA deformity was 3.8° of varus, and was corrected to 4.6° of valgus. The results of radiographic examinations in a full-length standing view showed that there was a good restoration of postoperative MA in all cases, with a mean angle of 0.4° of varus (Fig. 2). The position of the components was also good, evaluated by radiographic parameters including the LDFA (averaged 90.1°), the MPTA (averaged 90.5°), the sagittal alignment of femoral component (averaged 2.6°), and the tibial slop (averaged 3.6°).

Discussion

The CAS is used in joint arthroplasty to increase surgical precision and decrease the individual variability, and previous studies [8,9] have shown that compared to IM femoral and IM/EM tibial guiding systems, CAS-TKA could provide more accuracy of MA, better coronal and sagittal implant position, and less postoperative implant outliers for patients with primary knee osteoarthritis. Computer NA uses the centers of the femoral head, the knee joint, and the ankle to calculate the MA, helping the surgeon to restore MA and implant the prosthesis accurately without having to rely on the distorted anatomical landmarks or an IM guide. It is reasonable that CAS is potentially a useful alternative to conventional techniques in TKAs for knee arthritis in the presence of femoral hardware or with EA deformity where accurate restoration of limb alignment may be challenging. Historically, it has been reported that NA can help achieve accurate alignment correction in TKA for patients with retained implants [1,2,21] or EA deformity [3,13–16]. Tigani et al. [21] used CAS in conventional TKA for nine patients with EA femoral deformity and five patients with retained hardware after prior femoral fracture, and they reported that the postoperative mean values of MA were 0.9° and 1.4° of valgus, respectively. Manzotti et al. [1] also successfully restored the MA to a mean value of 0.9° of varus using CAS-TKA without a preceding implant removal in 16 patients with knee arthritis and retained femoral implants.

However, CAS-TKA using the conventional medial parapatellar approach usually requires additional quadriceps

Table 2 Results of radiographic examinations.

Patient no.	Implants	EA deformity (°)	MA (°)	LDFA (°)	MDTA (°)	FF (°)[a]	TS (°)
1	Plate	−5.6 (femur)	+2	90.6	92.8	*	2.8
2	Nail	−9 (tibia)	+1	89.3	91.5	3.4	4.6
3	Plate	−25 (femur)	−1.6	92.3	90.7	*	2.7
4	Nail	No	−1.3	91.2	89	2.3	3.4
5	Plate	No	−1.8	89.6	91	1.7	3.6
6	Nail	No	−1	89.8	88.7	2.2	4.2
7	Plate	No	+1.5	87.7	89.5	3.2	2.9
8	Plate	No	+0.5	90.6	91.2	2.8	4.3
Mean			−0.1	90.1	90.6	2.6	3.6

EA = extra-articular; FF = femoral flexion; LDFA = lateral distal femur angle; MA = mechanical axis; MPTA = medial proximal tibial angle; TS = tibial slope; − = varus; + = valgus.
[a] Asterisks signify data not collected because of inaccurate measurement using standard lateral radiograph in patients with extra-articular femoral deformity.

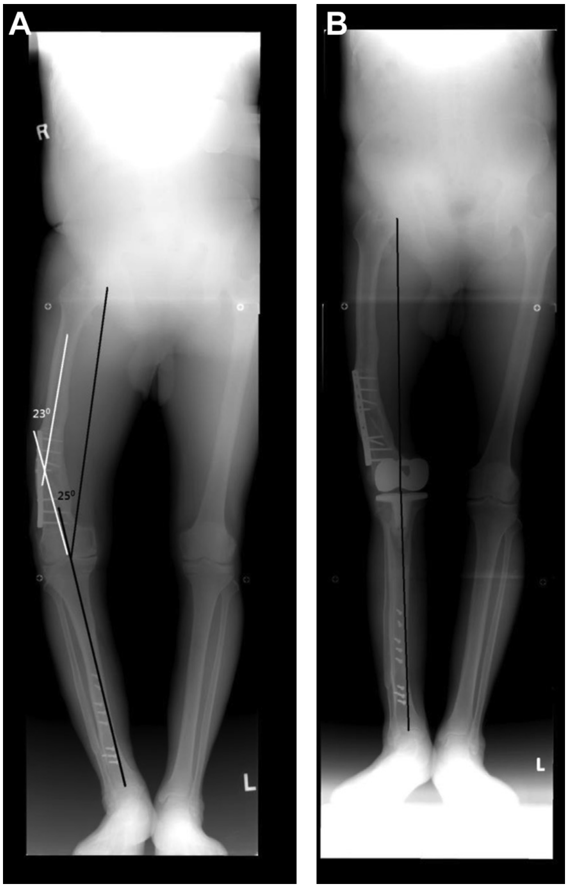

Figure 2. Radiographs of a 64-year-old man with knee arthritis in the presence of extra-articular femoral deformity and retained implants (Patient 3 in Table 1). (A) Preoperative full-length standing radiograph showing a coronal deformity of 25° of varus and a retained plate in the femur. The preoperative mechanical axis was 23° of varus. (B) Postoperative full-length standing radiograph showing good restoration of the mechanical axis. The mechanical axis was 1.5° of varus.

dissection for placing the femoral reference array, and it may be associated with a delayed recovery of the quadriceps during early postoperative rehabilitation [22]. Actually, the development of NA systems, addressing major challenges in TKA, enables less invasive surgery. MIS has gained popularity because it results in less postoperative pain, faster functional recovery, and shorter hospital stay than conventional TKA [17,23]. The better postoperative recovery in MIS-TKA is because of less soft-tissue dissection, including a relatively small skin incision and the limited damage to the extensor muscles and quadriceps tendon [17,23]. However, some studies point out that the limited surgical field in MIS-TKA may increase the incidence of postoperative component malalignment [24]. CAS has been reported to be effective in improving the precision of MA restoration and prosthesis positioning in MIS-TKA without increasing complications compared with a conventional approach [10]. However, MIS-TKA for patients with retained hardware and EA deformity in femurs may have higher incidence of component malposition and improper limb alignment because of inadequate surgical exposure [2]. To date, there have been few studies reporting the application of CAS in MIS-TKA for patients with femoral retained implants.

In this study, we performed CAS-MIS-TKA using a mini-medial parapatellar approach, which is the one most similar to the standard parapatellar approach, on eight knees with retained implants in the ipsilateral femurs. The results were comparable to those of previous studies using CAS in conventional TKA for patients with retained femoral hardware [1—3,21] and showed compatible accuracy with those of reports performing CAS-MIS-TKA in patients with simple primary knee osteoarthritis. It implied that CAS can help to restore the accurate MA with proper prosthesis orientation in MIS-TKA for such a complex knee disorder [10]. In addition to retained femoral implants, two of the eight patients in this study had a coexisting EA femoral deformity. EA deformity changes the anatomic axis and thus increases the difficulty in alignment restoration. The computer NA, offering objective information for bone cutting and prosthesis positioning, only takes into consideration the hip, knee, and ankle centers and ignores deformity of the femoral shafts. Therefore, CAS is considered a useful tool to help the surgeon implant the prosthesis in a position consistent with the true MA for a patient with distorted anatomy. Previous studies have shown that the results of CAS-TKA were comparable to those reported in studies of TKA with simultaneous femoral osteotomy [25] or intra-articular bone resection [26] for patients with EA femoral deformity. With the use of CAS in MIS-TKA, the two patients in this study with EA femoral deformity obtained an ideal postoperative MA within 2° of normal alignment. Similar results were also reported in a recent study by Kim et al. [12], who described their successful experience using NA-MIS-TKA in four knees with pure EA femoral deformity. Moreover, in one of the two cases, we successfully corrected the alignment of one knee with a preoperative mechanical axis of 25° of varus without corrective osteotomy.

Despite the benefits, there are some disadvantages with the use of CAS and MIS. First, the surgical time is longer compared to the conventional TKA. It has been reported that MIS-TKA averagely increases the surgical time by 10.49 minutes [27], and an additional 10—20 minutes would be required with the use of CAS, because of the insertion of process trackers and registration [28], which is consistent with our findings (about 5—10 minutes for MIS and 15 minutes for CAS). Nevertheless, the additional surgical time seems to be a minor inconvenience that can be compensated by early recovery and a significant increase in accuracy of implantation and can be reduced with longer experience [29]. Second, CAS is often thought to be technically demanding and involves a long learning curve. However, a previous multicenter study [29] has reported that for high-volume surgeons with more than 50 TKA per year, the beginners were immediately as accurate as the experienced users of the NA system, and that the learning curve for NA use flattened out after 30 implantations. This seems to be acceptable, given the additional information and the improvement in consistency provided by the NA system.

Despite the good clinical and radiographic outcomes in this report, there are some limitations in our study. First, only limited patients were enrolled. This is because of the rarity of such complex knee disorders and the initial experience with CAS-MIS-TKA in our institute. Second, this study presents data with a minimum follow-up of 2 years and the long-term results are still undetermined. Two years of follow-up is not long enough to assess the durability of knee arthroplasty. However, it is believed that the durability of TKA postoperative results is dependent on the overall knee alignment after surgery [30]. Malalignment can cause axial offloading on the components and affect the longevity of the prosthesis [31]. The restoration of neutral MA may ensure the durability of implanted prosthesis. Finally, we assessed the MA and component position using coronal long leg and sagittal standard radiographs. It was reported that some imaging errors may occur with this method, such as the flexion deformity and rotation between the femur and the tibia [32]. Computed tomography is a better tool to assess the true alignment of the lower limb and the orientation of component. However, we did not use computed tomography in routine postoperative follow-up in consideration of its cost and degree of radiation exposure. In conclusion, although our study is a report of short-term follow-up with limited cases, our results apparently show that the CAS can aid the surgeon in achieving accurate alignment and proper prosthesis positioning in MIS-TKA for patients with retained femoral implants and for whom IM rod guidance is impractical.

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